

Pilot of the Pollution Prevention Technology Application Analysis Template

Utilizing

Metall:X™ and Keyle:X™ Technologies

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DISCLAIMER

This document pilots the Pollution Prevention (P2) Technology Application Analysis Template (P2 template) on SolmeteX Inc. technologies. It is designed to assist the user in analyzing the application of pollution prevention technologies. While it provides a template for the general types of questions that you should ask when evaluating a P2 technology, it may not include all questions that are relevant to your business, or which your business is legally required to ask.

This document is not an official U.S. EPA or Army Corps of Engineers guidance document and should not be relied upon as a method to identify or comply with local, state or federal laws and regulations. EPA and the Army Corps of Engineers have not examined, nor do they or their contractor endorse, any technology analyzed using the P2 template.



Introduction

The intent of the Environmental Protection Agency (EPA) in developing and piloting the Pollution Prevention (P2) Technology Application Analysis Template (P2 template) is to promote the use of technology application analyses as a method of promoting and accelerating the introduction and use of new P2 technologies. The purpose of this technology application analysis is to assist users of P2 technologies in evaluating the applicability of this technology to their needs. In addition, this technology application analysis is an example which will assist vendors of P2 technologies in developing their own technology application analyses. The template itself, stripped of data from any particular analysis, is available from EPA - New England for the reader's use in comparing the topics covered in this analysis with the perhaps more complete range of topics listed in the template.

This technology application analysis concisely characterizes the main features of the technology, its benefits, the costs associated with its implementation, regulatory aspects, and lessons learned from the application experience.

This technology application analysis illustrates how the P2 template can summarize a technology, in this case Keyle:X™ and Metall:X™, innovative, proprietary metal removing adsorbents developed by SolmeteX Inc. of Billerica, Massachusetts. The flow of description in the template is a bit unusual in this pilot analysis because two very different classes of application are being described in one template.

SolmeteX technologies can be applied at the point of generation within a process or at the end-of-pipe just prior to discharge. Both the Keyle:X™ and Metall:X™ technologies are trademarked, and patents are pending for the SolmeteX system.

While this application is illustrative of how the technology is utilized in commercial P2 applications at a Boston area hospital, the technology is broadly applicable to regulated metals present in a variety of industrial wastewater streams such as from medical laboratories, metal plating operations, printing processes, photographic processes, and others. **In the applications described herein, Keyle:X™ and Metall:X™ accomplish treatment and provide an opportunity for recovery. In other applications, these technologies could accomplish source reduction (P2).** Additional information beyond that suggested in this technology application analysis is available from SolmeteX.

This application analysis is divided into seven sections:

- Introduction
- Description of P2 Technology
- P2 Technology Application
- P2 Technology Performance
- Cost Information
- Regulatory / Safety Requirements
- Lessons Learned / Implementation Issues



Description of P2 Technology

Industrial wastewater contains toxic metals, such as mercury, which must be removed from wastewater before it can be discharged. Conventional treatment methods such as precipitation and ion exchange are often not able to achieve the low regulatory limits for metal constituents at an acceptable cost.

The reagents used in clinical chemistry, commercial and hospital laboratories including pathology, histology and cytology laboratories, contain a significant quantity of contaminants including mercury, arsenic, chrome, cadmium, phenols, molybdenum, and silver. When discharged to sinks and drains whose piping connects to a larger drain system within a hospital, these reagents readily contaminate millions of gallons of wastewater from other sources within the hospital. In creating such a large volume of contaminated wastewater, hospitals risk violation of regulatory discharge requirements and subsequent fines.

The Keyle:X™ and Metall:X™ adsorbent technologies have been developed as potential alternatives to conventional metals removal technologies used for industrial wastewater treatment and site remediation activities. The Keyle:X™ resin is a chelator which selectively binds mercury and silver, while the Metall:X™ resin is an adsorbent for multivalent anions. As Keyle:X™ and Metall:X™ are intended to attack different components of metals in a waste stream, they can be used independently or in combination to remove metals from wastewater, depending on the contaminant constituents in the waste stream. Keyle:X™ and Metall:X™ are not strictly P2 technologies, but metals removal technologies which have significant P2 potential when used to provide point of generation systems to treat wastewater at the point of initial contamination, which prevents larger flows from being contaminated when waste streams are mixed downstream before discharge.

The following section describes the Keyle:X™ and Metall:X™ adsorbent technologies, giving general information on the major equipment, feed influent and product effluent, and energy / utility requirements. The applicability of this technology to industry is also described. In addition, the advantages and limitations in applying the technology are provided.

Technology Description: Resins and End of Pipe System

Overview of Resins and System

Keyle:X™: Keyle:X™ is an adsorbent which selectively binds mercury and silver. It is a divinyl benzene bead with a proprietary surface chemistry that allows high flow rates, high capacity, and greater selectivity than conventional adsorbents currently commercially available. Adsorbed metals can be recovered from Keyle:X™ by thermal destruction of the resin cartridges in a secondary metals recovery process. The binding method of Keyle:X™ is unlike that of conventional ion exchange technology in that it binds the metal through chelation as well as charge differences. There is no exchange with the Keyle:X™ system, no precipitation, rather adsorption and capture. The Keyle:X™ system includes pretreatment and resin columns wherein the adsorption of the metal is a combination of the pretreatment stage and the surface chemistry of the resin. Keyle:X™ systems typically have a more compact footprint than similar installed ion exchange systems as a smaller volume of resin is required due to increased binding kinetics of the SolmeteX technology.



Keyle:X™ structure has significantly more binding sites than the typical resin due to a greater surface area. This allows for a shift in the ionic species by pretreatment so that metals are more readily bound when compared with the performance of other methods. Keyle:X™ selective chelating group allows for a much stronger binding constant.

Metall:X™: Metall:X™ is a mixed metal oxide that adsorbs multivalent anions of metal into its crystalline structure. Its technology is based on a plate-like structure that selectively binds multivalent anions, allowing for the metals to be incorporated directly into the structure. Metal concentrations of the final effluent can be reduced to low mg/L, which typically meet regulatory discharge limits. Metall:X™ binding with target metals is irreversible to the extent that the end product passes TCLP analytical requirements.

Metall:X™ is a drop-in technology substitute for conventional hydroxide precipitation (powder form) and ion exchange systems (granular form). The following presents a conceptual sketch of the treatment process.

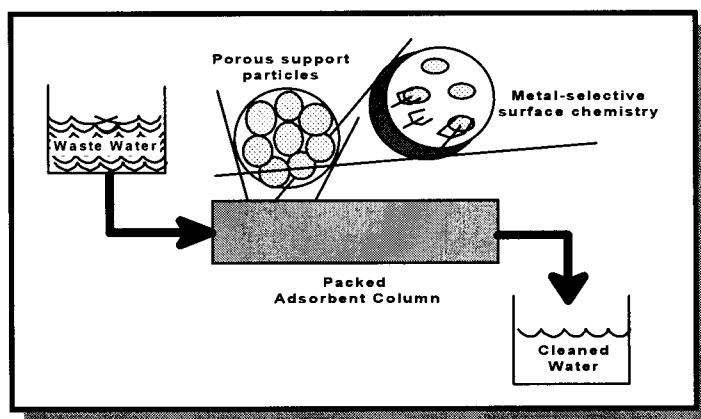


FIGURE 1 - CONCEPT SKETCH OF THE TREATMENT PROCESS

Using the Keyle:X™ and Metall:X™ resins in combination, the SolmeteX system removes the toxic metals typically found in clinical analyzer waste streams. This technology allows SolmeteX to provide point of generation systems to treat smaller flows and end-of-pipe solutions for large flows. Treatment at the point of initial contamination will prevent larger flows from being contaminated when the waste streams are mixed downstream before discharge.

Detailed Description of Resins

The Keyle:X™ technology is a series of chemical building blocks that construct highly specific chemical binding sites with a surface texture (referred to by the vendor as a "fuzzy" structure) to capture target metals. These building blocks are made up of chemical groups as chelators, or organic molecules, that form a cavity into which a specific type of metal atom will fit like a "lock and key" and chemically bond to multi-branched polymers on support beads that provide a "fuzzy" surface tailored to removal of silver and mercury.

The Keyle:X™ adsorbent products are based on the same polymer bead support technology used in water treatment systems today. The adsorbent beads are surface modified through a proprietary coating chemistry and coupled with functional groups that selectively adsorb metals from the wastewater stream down to low ug/L levels.



A key element in the SolmeteX technology is to utilize these polymeric or "fuzzy" structures for the coating chemistry to increase capacity and capture of the multivalent metal anions. In conventional adsorbents, the selective functional groups are directly coupled to the surface of the porous support matrix beads. This limits the amount of selective groups that can be coupled, and thus the binding capacity. With ion exchange, the functional groups are small, so this is not a problem. Conversely, chelators are rather bulky, and by hanging the groups out on a "fuzzy" surface, the capacity of the adsorbent can be greatly increased.

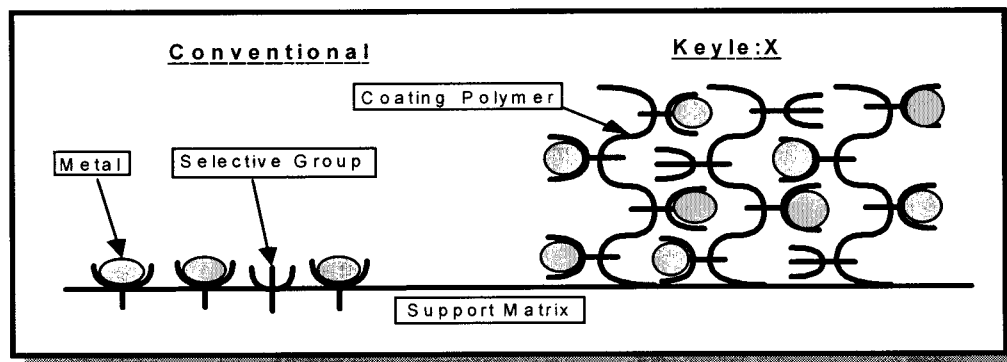


FIGURE 2 - KEYLE:X™ STRUCTURE

Unlike conventional resins that attach the binding chemistry to the surface, the building block/ "fuzzy" chemistry approach allows SolmeteX to construct 3-Dimensional structures on the surface and then attach the binding chemistry to the ends of the structures, yielding a high adsorption capacity.

Detailed Description: End of Pipe System:

SolmeteX has also developed system to treat wastewater as an end-of-pipe application. This technology:

- May be used for treatment of large volume mercury contaminated waste streams.
- Uses the proprietary Keyle:X™ resin in combination with a pretreatment technology to reduce the mercury to levels to below the MWRA enforcement limit of 1 ug/L. Massachusetts regulations prohibit the discharge of mercury. The MWRA enforcement limit of this prohibition is 1 ug/L.
- Can be sized to handle any influent flow rate from 1 liter per hour to 150 gallons per minute and larger.

Technology Applicability: Resins and End of Pipe System

This section describes the applicability of the point of generation technology to users, the development history of both the Metall:X™ and Keyle:X™ resins and their associated systems, and the advantages/limitations claimed by SolmeteX.



Applicability to Other Industries/Users

The Metall:X™ and Keyle:X™ technologies have a wide range of applications in other industries, and are generally applicable to most industrial waste streams requiring metals removal prior to discharge.

Metall:X™	
•	Metal plating
•	Computer chips/Semiconductors
•	Contaminated groundwater
•	Printing and photo processing
•	Power utilities
•	Mine runoff
▶	X-ray waste streams

Keyle:X™	
•	Clinical lab wastes
•	Commercial lab wastes
•	Chlor-alkali plants
•	Medical waste incineration

In the above industries, metals are used in industrial process operations and may also be present at remediation sites. They are commonly combined with chelate to hold the metal in solution.

With conventional metals precipitation technology, additional chemical treatment is required to break the chelate/complex prior to precipitation. Common chelating/ complexing agents associated with these processes include ammonia, citrates, tartrates, quadrol, phosphates, and EDTA. Heavy metals that tend to readily form metal complexes in the presence of these agents include cadmium, copper, lead, nickel, and zinc. Complexed metals must be segregated from non-complexed metal waste streams, and treated separately to break the complex.

The ability of Keyle:X™ to selectively recover and reuse process chemistries fills a technology gap for hospitals and photo-finishing laboratories. Upon refinement of the recovery process, Keyle:X™ will potentially add another level of polishing to rinse waters making the wastewater more amenable for recycling directly back into the process line.

The ability of Metall:X™ to bind multivalent anions allows it to be used for the direct treatment of complexed/chelated metals such as chromate ions (hexavalent chromium) and metal-EDTA complexes without the need for additional treatment steps that are necessary with conventional treatment. The need for coagulant and polymer flocculant additions is minimized or eliminated with the use of Metall:X™ chemistry.

Development History of Resins

SolmeteX core technology is based on the application of conventional industrial water treatment practice in combination with advances in separation technology made by the biopharmaceutical industry in the last 10 years based on novel metal-binding chemistries.

The Massachusetts Strategic Envirotechnology Partnership (STEP) provides a range of technology and business development services including third party verifications. STEP evaluated Metall:X™ performance capability at the bench scale level and supported the Keyle:X™ demonstration at the area hospital as an end-of-pipe treatment technology. STEP's 1997 assessment report states that both Metall:X™ and Keyle:X™ are "promising alternatives to conventional industrial wastewater



treatment technologies." For more information on the STEP report, please contact Paul Richard at (617) 727-9800 x449.

Application History: End Of Pipe System:

TABLE 1 - APPLICATION HISTORY OF END OF PIPE SYSTEM

Time	Location	Scale	Purpose	Results
January 1996	Royal Oaks Giant Mine Canada	Lab, Field	Remove As, CN	Both species successfully removed from the wastewater.
January 1996	Colomac Mine Canada	Lab, Field	Remove As, Cu, CN	As, Cu removed. CN destruction chemicals had to be used in conjunction with the Metall:X™ to treat the wastewater.
June 1996	Hospital Boston, MA (name withheld at client request)	Pilot	Remove Hg from incinerator scrubber water.	Removed >99.9% of Hg with feed levels of 500-10,000 ug/L to discharge levels under 5 ug/L when the stream is pretreated.
July 1997	Boston Globe, Billerica, MA	Commercial Application	Remove Ag from photo-processing wastewater.	Granular Metall:X™ reduced AG to below target discharge level of 0.2 mg/L with feed levels up to 0.63 mg/L with biocide addition.
July 1997	HoltraChem Co.	Lab, Field	Remove Hg from process water and storm water run-off.	Captured >99.5% of Hg with feed levels of 15 and 129 ug/L to discharge levels under 1 ug/L Hg when pretreated.

Lessons Learned: Resins and End of Pipe System

Bench and pilot scale applications of the Metall:X™ technology have indicated satisfactory performance in the selected applications. The following presents lessons learned during development of Metall:X™.

Metall:X™

The following lessons learned present issues which have already been incorporated into the design of the SolmeteX systems:

- ▶ For removal of chromates from wastewater while using the Metall:X™ technology, a system operating at pH greater than 3 is most effective. The performance and integrity of the resin is compromised when it is exposed to waste streams with a pH below 3.
- ▶ Competition exists between sulfates and the target ion for the Metall:X™ bonding site for some anions. Additional studies showed successful removal of EDTA and chromates using a "co-precipitation" configuration.

The following lessons learned are issues which are dependent on the user of the system:

- ▶ For removal of EDTA copper complexes while using the Metall:X™ technology, a system operating at pH greater than 6 is most effective. It is the responsibility of the user to adjust the pH of the waste stream to within the suggested operating range.

The following lessons learned represent unresolved issues:

- ▶ Metall:X™ is effective in removing complexed cyanide, but not free cyanide.



The following presents lessons learned during development of Keyle:X™.

Keyle:X™

Keyle:X™ is shown to have chemical stability at high and low pH ranges, in the presence of an oxidizer, as well as potential fouling agents.

Proprietary pretreatment is necessary for complete removal of mercury.

Well-distributed flow through the vessel containing the resin is important to ensure that the resin is most efficiently utilized.

Technology Description: Point of Generation System

Detailed Description

SolmeteX has developed the Effluent Management System (EMS), a simple, compact point of generation system which incorporates SolmeteX's metal removal resin columns with a pretreatment process that optimizes the metal removal efficiency of Metall:X™ and Keyle:X™. With a footprint of approximately 30" H x 24" W x 22" D, the EMS point of generation system fits under the laboratory sink for hospital applications.

- The EMS point of generation treatment system is fed wastewater from an automated clinical analyzer producing up to 40 liters of waste per hour. It is connected directly to a laboratory clinical analyzer or sink drain and operates in "hands-off" mode.
- The system is designed to treat and remove a waste stream with a mix of toxic metal contaminants, including mercury, arsenic, silver, zinc, lead, cadmium, molybdenum, copper and other metals to below discharge limits.
- The EMS system uses a blend of patented removal resins and adsorbents in combination with a pretreatment technology. The system also utilizes sanitization/disinfectant to provide active control and prevention of any biological contaminants that may be present in the waste stream.
- The disposable cartridges are sized to provide a large safety margin and prevent possible discharge of untreated waste. The cartridges must be changed out approximately every ninety days or after a predetermined number of liters of wastewater has been processed. The cartridges are self sealing to prevent any spillage.

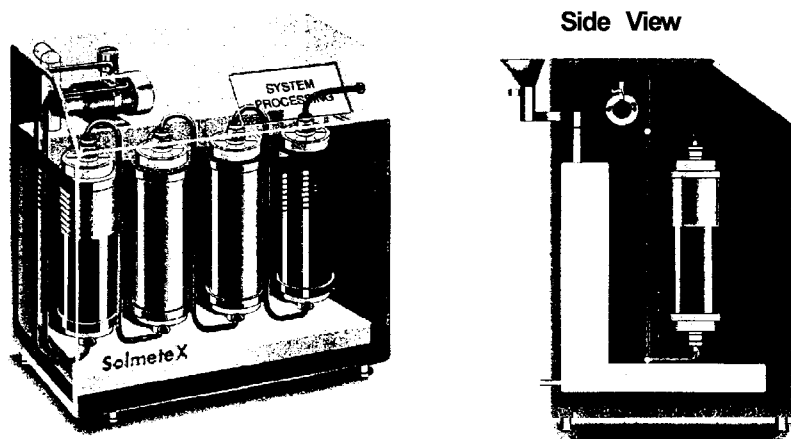


The EMS system, pictured below, consists of a series of columns that:

- > pretreat the waste,
- > remove select metals,
 - Keyle:X removes mercury only for recycle
 - Metall:X removes all other target metals
- > disinfect the processed stream.

Service is easily accomplished, on a dry column basis, by popping out the old/spent resin columns and replacing them with new/fresh resin columns.

The used columns are shipped out for reclamation (Keyle:X) or disposal as a non-hazardous waste (Metall:X).



(unit size: 30" H x 24" W x 22" D)

FIGURE 3 - EFFLUENT MANAGEMENT SYSTEM (EMS)

Technology Applicability: Point of Generation System

Development History

The most effective cell fixatives, tags, and preservatives are mercury and other metal based solutions. Although used in small amounts, this material is routinely discharged via lab sinks to the sewer system adding to a persistent mercury problem in wastewater and the environment. SolmeteX at the request of hospital equipment manufacturers designed a system:

- ▶ Compatible with standard blood analyzer equipment;
- ▶ Space efficient (30"H x 24"W x 22"D) and effective (0.5 ug/L) at removing mercury at the point of generation;



- Fill the technology void between effective source reduction strategies implemented by hospitals and area end of pipe limitations. Some Boston area hospitals, in an effort to comply with the effluent mercury enforcement limit of 1 ug/L (0.001 mg/L), found they could reduce mercury concentrations from 12.0 mg/L to 0.012 mg/L using source reduction strategies. The EMS can fill the void between 0.012 mg/L and 0.001 mg/L.

Application History

TABLE 2 - APPLICATION HISTORY OF POINT OF GENERATION SYSTEM

Time	Location	Scale	Purpose	Results
1997	Histology Laboratory Boston, MA (name withheld at client request)	Commercial Application	Remove Hg from laboratory rinse water at hospital.	Removed >99.99% of Hg with feed of 350 mg/L to discharge levels below 1 ug/L when pretreated.

Lessons Learned: Point of Generation System

As the EMS point of generation system was developed in response to the need for mercury reduction in hospital laboratories, many of the lessons learned during development of the EMS point of generation system relate directly to conditions present in hospital laboratories, as stated below. The following lessons learned during the development of the system have been incorporated into the design of the standard unit.

EMS Point of Generation System:

A compact footprint was necessary to fit under the hospital laboratory sinks, and into other restricted spaces in laboratory areas.

A multi-adsorbent system was needed due to the presence of metals other than mercury in use in the health care industry.

Waste must be oxidized/disinfected as it enters the surge tank. Pretreatment is necessary due to non-metallic interferences from proteins, serums, and other organics.

Self-monitoring of the system was necessary, as ease of use by the health care staff was mandated.

Incorporation of audio/visual alarms and signals for system maintenance and cartridge change-out was necessary because the system is self-monitoring. Audio/visual alarms and signals will alert health care staff present in the laboratory at that time.



P2 Technology Application

This section describes the use of the SolmeteX technology at a Boston area hospital, the details of the technology location within the hospital, and how the hospital wastewater was affected.

P2 Technology Application: Point of Generation System

General Setting Note: These settings were chosen to pilot test applications, rather than display the full reuse/recycling potential of the technologies.

The point of generation application is being used at a hospital location in the greater Boston area where waste mercury is generated at a histology laboratory. The histology laboratory generated a volume of wastewater containing elevated concentrations of mercury and which subsequently contaminated a much larger waste stream of previously uncontaminated water within the hospital wastewater system. The metal source and concentration at this point was relatively consistent over time.

The end-of-pipe application is being used at a hospital location in the greater Boston area where waste mercury is generated at a medical waste incinerator. In contrast to the histology laboratory, the medical waste incinerator received and processed a wide variety of wastes from various locations within the hospital complex. Source, type, and concentration of mercury varied widely depending on waste received with mercury levels up to six times the average influent mercury level.

Technology Implementation At Manufacturing / Industry Plant Site

The SolmeteX point of generation system was used to treat rinse water from a histology laboratory at a Boston hospital in 1997. The SolmeteX technology, using the Metall:X™ and Keyle:X™ resin columns and a pretreatment system was implemented, treating the drain water to remove mercury. The following presents the location of the SolmeteX technology within the laboratory.

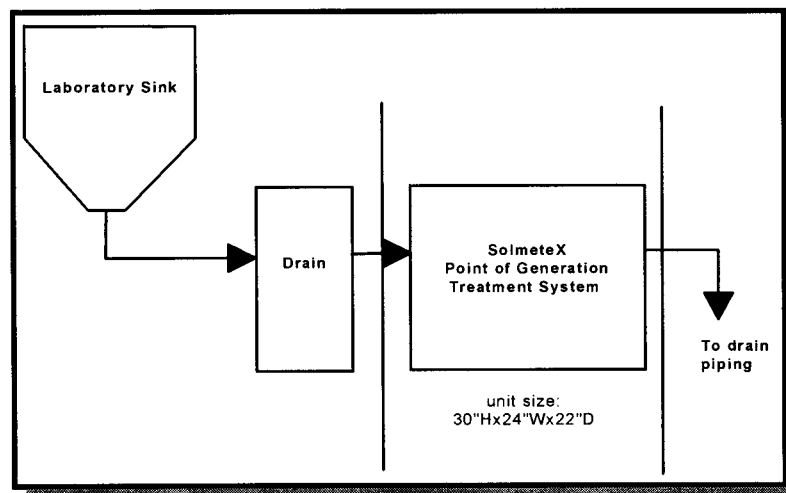


FIGURE 4 - POINT OF GENERATION LOCATION WITHIN THE LABORATORY



This point of generation system consists of an oxidant/disinfectant pretreatment system, a surge tank, and a chemical feed pump, followed by the adsorbent system columns in series. The effluent from the system, or treated water, is discharged directly to the drain. Column change-out is a function of concentration and flow and can be based on time or volume. Following is a process flow diagram of the SolmeteX EMS technology.

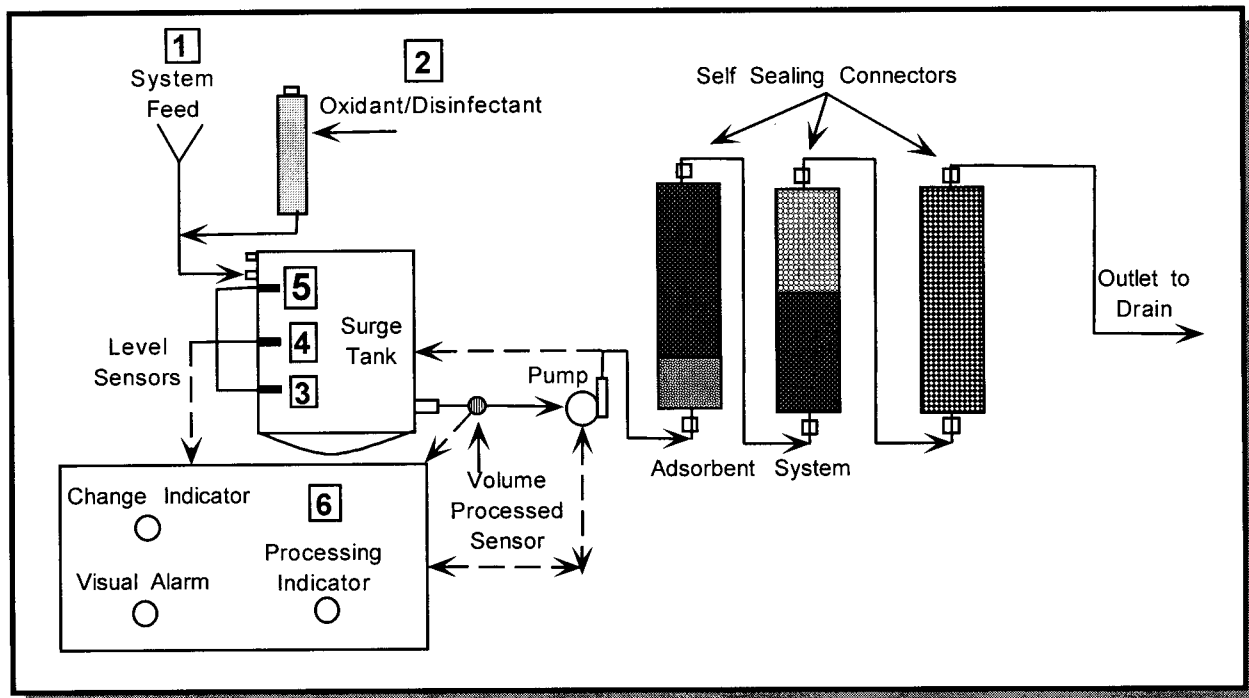


FIGURE 5 - POINT OF GENERATION TREATMENT SYSTEM SCHEMATIC

The operating sequence is as follows:

1. System receives waste from analyzer at approximately 7 L/hr.
2. Waste is oxidized and disinfected as it enters the tank. Sensors and alarms to indicate pending loss of oxidant/disinfectant can be incorporated into the SolmeteX system as an option. Currently, the oxidant/disinfectant level is monitored by manual observation only.
3. When the waste reaches the low level sensor, the pump mixes the pre-treated waste.
4. When the waste level in the tank reaches the second level control the flow direction is changed and the waste is pumped through the cartridges and out to the drain.
5. The high level sensor is hooked to the audio/visual alarm to notify the operator or user of a problem such as a plugged system or broken pump.
6. The change indicator (visual and audio alarm) will come on after either a predetermined number of days or volume of flow through the system has been reached.

Operating temperature is maintained from 5 - 50 C, pH is kept at 3 - 11. A pH control system is incorporated into the design of the SolmeteX unit on an as-needed basis. If the existing system



with which the SolmeteX unit is integrated is not already equipped with a means for pH control, a system is incorporated into the SolmeteX unit.

Metals removed include arsenic, cadmium, chromium, lead, mercury, molybdenum, nickel, silver and zinc.

P2 Technology Application: End of Pipe System

General Setting Note: These settings were chosen to pilot test applications, rather than display the full reuse/recycling potential of the technologies.

The SolmeteX end of pipe system with Keyle:X™ is being used to treat stack gas scrubber water from a medical waste incinerator at a Boston-area hospital. The influent mercury levels were highly variable often exceeding the MWRA mercury discharge enforcement limit of 1 ug/L by 10,000 fold. Similar facilities dispose of thousands of gallons of water per month by hauling to a hazardous waste treatment facility at a cost of approximately \$3 per gallon. The current analysis of the waste stream shows the discharge level of mercury to be below 0.5 ug/L.

The Keyle:X™ system utilized two series-connected columns of Keyle:X™ adsorbent to remove over 99.99% of the mercury from their scrubber water. The user is now able to recirculate or discharge their water. This system provides the user significant savings in mercury/arsenic disposal.

Technology Implementation At Manufacturing / Industry Plant Site

The SolmeteX end of pipe technology for removing mercury from wastewater was operated at a Boston-area hospital. The SolmeteX technology, using the Keyle:X™ resin columns and a pretreatment system, was implemented at a medical waste incinerator, treating the scrubber water to remove mercury. The following presents the location of the SolmeteX technology within the hospital.

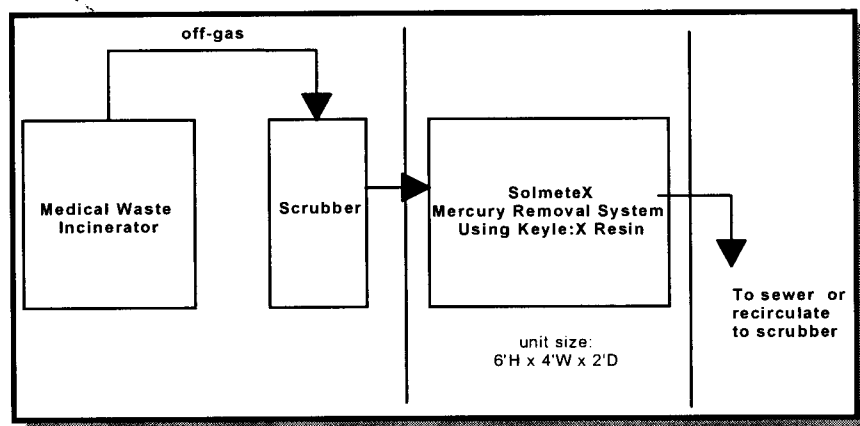


FIGURE 6 - END OF PIPE TECHNOLOGY LOCATION WITHIN THE HOSPITAL

The SolmeteX end of pipe mercury removal technology consists of a chlorination pretreatment system, a reaction/mixing tank, a chemical feed pump, 10 and 1 micron filter cartridges in series, followed by four Keyle:X™-Hg resin columns. Pressure gauges are located before and after each



unit process, and sample ports are located at critical points in the process to monitor system performance. Valves are included to isolate each unit process and facilitate filter and resin cartridge change-out. The following presents a process diagram of this SolmeteX technology.

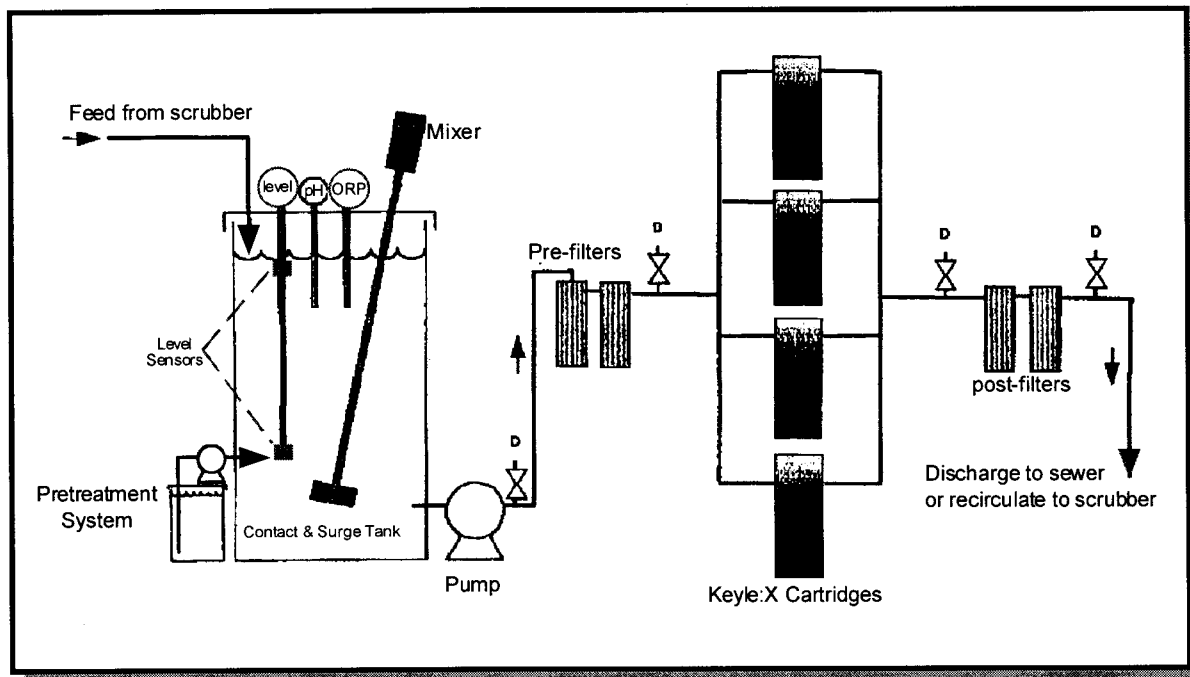


FIGURE 7 - END OF PIPE TREATMENT SYSTEM SCHEMATIC

The operating sequence is as follows:

1. The system receives wastewater from the scrubber at approximately 1.3 gallons per minute via an inlet above the pretreatment (surge/contact) tank.
2. Pretreatment of the wastewater in the tank is controlled by a signal from the ORP monitor to ensure the appropriate level of pretreatment.
3. Pretreatment is initiated when the wastewater level in the tank triggers the low level sensor relay.
4. When the mid-level sensor is activated and the ORP monitor is above threshold level, water is pumped from the tank through a 3-way actuated valve and through
 - (a) pre-filters
 - (b) Keyle:X cartridges
 - (c) post-filters
 - (d) discharge outlet
5. A high level sensor activates audio and visual alarms in the event of pump failure, clogging or general system failures.
6. Operating temperature is approximately 50C, pH is kept between 6.0 and 9.5.



P2 Technology Performance

This section presents performance data for the SolmeteX point of generation technology application in the histology laboratory at the hospital. The performance goals and technology performance are described by summarizing the application runs made and the results achieved. Pilot studies are presented for three end-of-pipe system applications.

P2 Performance Goals

This section presents the major P2 goals of the SolmeteX technology which determine the basis for performance evaluation.

- ▶ Achieve regulatory discharge limits for target metals in waste stream.
- ▶ Recover 99.99% of target metals for reuse or resale.
- ▶ Reduce waste sludge generation by 20 - 25% as compared to traditional precipitation technologies.

Technology Application Test Cases: Point of Generation

The following presents application test cases of the point of generation system at the histology laboratory in the Boston area hospital. The results are presented in the following section.

Histology Laboratory: The following summarizes the point of generation application for the rinse water at the histology laboratory in the hospital. The results of this application are presented in the following section.

- The laboratory generated a small amount of rinse water that had a mercury level of 350 mg/L and contaminated over 500,000 gallons of water to beyond the discharge limit upon discharge down the drain. The sink pipe, down which the mercury-contaminated waste was discharged, connected to a larger piping system in the hospital network. Therefore, when the mercury-contaminated wastewater from the sink drain mixed with the water from other areas of the hospital not initially contaminated with mercury, the entire mixture became contaminated with mercury.
- A small point of generation system was installed under the sink in the lab to treat the rinse water to below the MWRA 1 ug/L mercury discharge enforcement limit. Massachusetts regulations prohibit the discharge of mercury. The MWRA enforcement limit of this prohibition is 1 ug/L.
- The Keyle:X™ system utilized two series-connected columns of Keyle:X™ adsorbent to remove the mercury.
- Flow was set at approximately 7 l/hr. System capacity is approximately 20 l/hr. The flow rate of rinse water into the sink is independent of the system flow rate. The rinse water flows from the sink drain into a holding tank, which is part of the SolmeteX system. Flow from the holding tank is regulated at the predetermined setpoint.



- Operating temperature was 5 to 50 C, pH was 3 to 11.

P2 Technology Application Results: Point of Generation

The following presents results of the testing and application of the SolmeteX technology.

Histology Laboratory: The following summarizes the application results from the histology laboratory.

- ▶ System achieved effluent concentrations of <0.5 ug/L Hg
- ▶ System effectively treated the influent stream at a varying level of Hg, ranging from 1,100 ug/L to 5,840 ug/L.

TABLE 3 - HISTOLOGY LABORATORY RESULTS

Influent Hg (ug/L)	Effluent Hg (ug/L)	Influent Hg (ug/L)	Effluent Hg (ug/L)
1100	0.2	1800	0.5
4800	0.2	3640	ND
2890	0.5	5840	ND
1222	ND		

Technology Application Test Cases: End of Pipe

The following presents application test cases of the end-of-pipe system at the incinerator scrubber in the Boston area hospital, at HoltraChem Co., and at the Boston Globe. The results of the test cases are presented in the following section.

Mercury Removal from Medical Waste Incinerator Scrubber Water: The following presents a brief summary of the end-of-pipe application at the Boston area hospital. A summary of the results for this application are presented in the following section. The study performed by SolmeteX to remove mercury from the scrubber water from a medical waste incinerator included the following:

- Flow was set at 1.3 gallons per minute, equivalent to one bed volume (BV) per minute for each Keyle:X™ column or 0.5 BV/min for the whole system.
- For the first month of testing, three samples were collected per day of operation: (1) after the incinerator was started but before the waste was burned, (2) after about an hour of burning, and (3) several hours later at the end of the day.
- Mercury analysis was performed using EPA method 245.1 and 1631 (for comparison). Method 1631 allows for a detection limit of 10 ppt (parts per trillion) as compared to a 200-400 ppt detection limit for method 245.1.
- In addition to the mercury analysis, field measurements for pH and temperature as well as physical observations (visual, odor) were collected.

Mercury Removal Using Keyle:X™ for HoltraChem Co.: In July 1997, SolmeteX tested the performance of the Keyle:X™ adsorbent system on mercury contaminated process and storm water



run-off samples from HoltraChem Co. The following summarizes the study including procedures and operating parameters of the system. Results are presented in the following section.

- Two 39 ml columns (2.5 cm internal diameter) were packed, rinsed with de-ionized water, and placed in series. Column bed depth was 8 in.
- Pretreated samples were pumped through the column at varying flow rates, both at room temperature and heated to 50-60°C.
- The concentration of mercury in the process water feed stream was much greater than that in the storm water feed stream. The process water feed concentration was 128.9 ug/L Hg, at a pH of 8.08. The storm water feed concentration was 15.27 ug/L Hg, at a pH of 7.78.
- At least 4 BV passed through each column before sampling to allow system to reach equilibrium. Samples were collected after each column, yielding two contact times for each pump setting.

Silver Removal from Boston Globe Process Water Using Metall:X™: In July, 1997, SolmeteX used granular Metall:X™ to treat photo-processing rinse, fixer, and developer wastewater containing ionic and complexed forms of silver at the Boston Globe facility in Billerica, MA. The following summarizes the study including procedures and operating parameters of the system. The results of this study are presented in the following section.

- System components included: 300 gal. Holding tank with stand, biocide with injection pump, feed pump with flow control valve and flow meter, 5 micron cartridge filter, and 55 gallon flow drum of Metall:X.
- 3 Phase evaluation, over a 25 day period. (1) Rinse water only (lowest silver content). (2) Fixer added to rinse water (increased silver and thiosulfate levels). (3) Developer added to combined waste stream (high in silver, thiosulfate and EDTA complexing agents). A 250 ml sample was collected from each waste stream and analyzed using EPA Method 200.7.
- Varying feed concentrations of silver, up to 0.63 mg/L in the combined feed stream.

P2 Technology Application Results: End of Pipe

Mercury Removal from Medical Waste Incinerator Scrubber Water: The following summarizes the results of the field application to demonstrate the effectiveness of the SolmeteX end-of-pipe system on the removal of mercury from medical waste incinerator scrubber water, as described in the previous section.

- The SolmeteX system is consistently able to remove >99.9% of the mercury with feed levels of 500-10,000 µg/L to discharge levels under 1 µg/L total mercury (using EPA 245.1) when pretreatment of the stream is included.
- In feed streams with high particulate and organic loads, pretreatment is clearly necessary. Removal efficiency rises from approximately 75% to over 99.9% with pretreatment.
- The temperature of the feed was typically at approximately 50°C. The field measured pH ranged from 6.0 to 9.5.



TABLE 4 - FIELD COMPOSITOR RESULTS, METHOD 245.1: MEDICAL WASTE INCINERATOR SCRUBBER WATER

Date	Feed Hg Concentration (ug/L)	Effluent Hg Concentration (mg/L)
10/23/96	1.1	0.2
10/31/96	<0.2	<0.2
11/13/96	11.1	<0.2
11/20/96	2547	0.2
12/04/96	3640	<0.4
12/11/96	2890	<0.4
12/17/96	0.5	<0.4
01/08/97	<0.4	<0.4
01/22/97	No Test Taken	<0.4
01/30/97	0.5	<0.4
03/05/97	No Test Taken	<0.4
03/26/97	1410	0.6
04/23/97	581	<0.4

As presented above, the effluent treated by the SolmeteX system tested below compliance concentrations. The lack of appropriate pretreatment is the reason for the test results greater than 1 ug/L.

Mercury Removal Using Keyle:X™ for HoltraChem Co.: The following presents the results of the end-of-pipe mercury removal application performed for HoltraChem, as described in the previous section.

- At contact times of 3 minutes or more, >99.5% of Hg was removed from both the process water and storm water run-off to discharge levels of <200 ppt.
- All treatment times brought samples to <1ug/L Hg, within regulatory discharge limits.
- Discharge level of the storm water sample was 8 ppt, which is consistent with the level in ultrapure water blanks.

TABLE 5 - SUMMARY OF RESULTS: HOLTRACHEM STUDY

	Contact Time (min.)	Hg Concentration (ug/L) after Keyle:X™	Hg Concentration (ug/L) after Keyle:X™ and filtration
Process Water	7.72	0.055	0.05
Neat Feed: 104.5 ug/L	3.86	0.118	0.124
Oxidized Feed: 126.9 ug/L	3.12	0.085	0.097
	1.56	0.612	0.772
Storm Water	13.68	0.008	0.008
Neat Feed: 11.32 ug/L	6.84	0.046	0.019
Oxidized Feed: 15.27 ug/L	3.47	0.022	0.016
	1.73	0.152	0.057



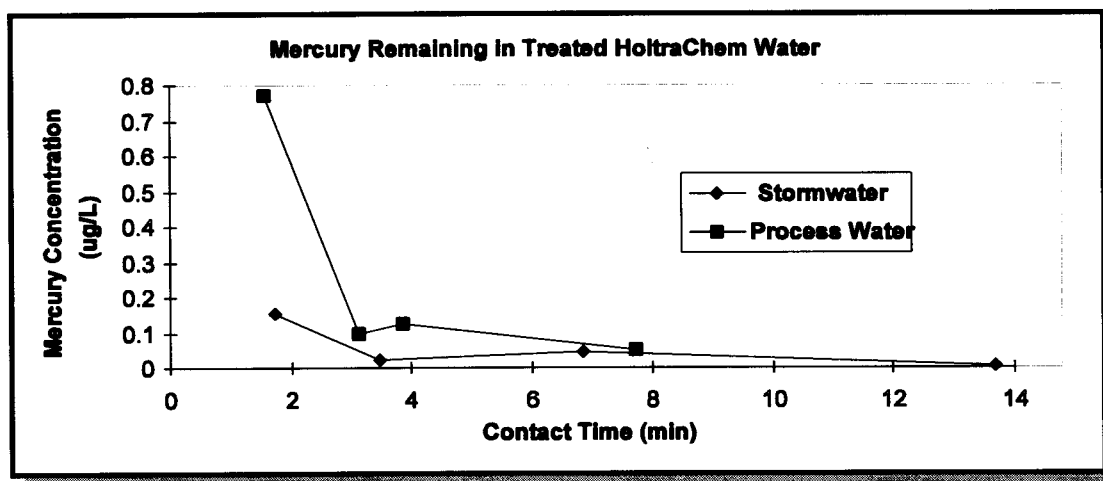


FIGURE 6 - HOLTRACHEM RESULTS

Silver Removal from Boston Globe Process Water Using Metall:X™: The following presents a summary of the results of the end-of-pipe silver removal performed for the Boston Globe facility, as described in the previous section.

- Approximately 34,858 mg silver captured by Metall:X™.
- Mean discharge concentration of 0.07 mg/L Ag and median discharge concentration of 0.06 mg/L both well below the MWRA Metropolitan Boston Sewer Service Area discharge limit of 2.0 mg/L Ag.
- Addition of a biocide was necessary to prevent biological growth that fouled the column. (See result of 7/8/97 in table below).
- Metall:X™ removed all forms of silver and complexes regardless of influent concentration.

TABLE 6 - SILVER LEVELS IN TREATED DISCHARGE WATERS

Sample Date	Feed Type	Effluent Silver Concentration (mg/L)
7/1/97	Rinse	ND
7/2/97	Rinse	0.11
7/3/97	Rinse	0.05
7/3/97	Rinse	0.08
7/7/97	Rinse	0.15
7/8/97	Rinse	0.24 (bacterial fouling of column)
7/11/97	Rinse & Fixer	0.08
7/14/97	Rinse & Fixer	0.03
7/15/97	Rinse & Fixer	0.09
7/16/97	Rinse & Fixer	0.02
7/17/97	Rinse & Fixer	0.02
7/21/97	Rinse, Fixer, & Developer	ND
7/22/97	Rinse, Fixer, & Developer	0.10
7/23/97	Rinse, Fixer, & Developer	0.03
7/24/97	Rinse, Fixer, & Developer	0.04
7/25/97	Rinse, Fixer, & Developer	0.06



Comparison with Existing/Traditional Technology

This section provides a comparison of the traditional technology and the SolmeteX technology. Note that the comparison was made by SolmeteX.

TABLE 7 - TECHNOLOGY COMPARISON

	SolmeteX Keyle:X™	Ion Exchange⁵ (typical)	Molecular Sieve⁵ (typical)
Bed Volume/Hour¹	60.0	2.5	2.0
Binding Constant²	10 ²⁹	10 ¹¹	10 ³¹
Resin Volume/GPM Flow (gallons)	1.0	25.0 - 30.0	30.0
Sizing Cost/GPM (\$) ³	1500-2300	1625 - 2350	90,000
Dynamic Capacity (mg/g dry resin)⁴	180	N/A	N/A
Treatment Cost/1000 gallons (\$) ⁴	3.68	N/A	N/A

Notes: 1-Approximate, assuming a moderate level of contamination.

2-Approximate, to the nearest order of magnitude.

3-Cost of resin required to treat one gallon per minute of flow.

4-For HgCl₂, under laboratory conditions running at 1 bed volume per minute, at 1 mg/L Hg.

5-Ion exchange and molecular sieve information taken from published information from manufacturers of these technologies.



Cost Information

This section presents cost information associated with the design, construction, startup, and operation of the P2 technology. This discussion provides the name of the company supplying the information presented and the costs estimated in current US dollars.

Capital Costs

It is anticipated that capital equipment costs would be equivalent to or less than those for conventional ion exchange or carbon adsorption installations, because the high binding constant efficiency of Keyle:X™ will require smaller systems for an equivalent flow rate.

The SolmeteX product line contains a number of systems which are designed to treat Clinical Laboratory Waste and reduce the concentration of toxic metals to below the permitted discharge levels. The most cost effective method for treating contaminated clinical waste is to treat as close to the point of generation as possible and to therefore reduce the volume of waste that must be treated by any traditional end of pipe system.

The economics of the systems will vary depending on the concentration of the toxic metals being treated and the amount of water the system must process. It is recommended that a sample of the clinical waste be analyzed and the waste stream characterized for the proper system design.

TABLE 8 - CAPITAL COSTS

Item	Cost
EMS System - Includes Keyle:X™ and Metall:X™ resin columns, pretreatment and disinfectant systems.	\$5,750*
Cartridge Replacement Kit - Includes fresh cartridges and return packaging for spent resin cartridges.	\$750

*Capital costs presented in 1998 US dollars

Operating Costs

The most significant costs associated with ion exchange are the costs of the resin material itself. Due to the fact that the Keyle:X™ structural design allows for greater per unit capacity, the Keyle:X™ material is more cost effective than existing ion exchange media, according to SolmeteX. In addition, the ability to retort the Keyle:X™ material to recover the mercury would potentially greatly increase its cost-effectiveness.

The operating cost per site can vary but based on current system pricing for the EMS point of generation system, and on an assumption of processing 105 gallons per day (10 hr/day, 5.5



day/wk) with an influent level of mercury at ≤ 2.8 mg/L, the average resin replacement cost to treat a waste stream with 2.8 mg/L of mercury or less is approximately 9.9 cents per gallon.

For the above referenced system, no power or fuels aside from approximately 10 amps of electricity, using a standard wall outlet, are required. Space requirements are substantially less than conventional systems due to the greater efficiency of these systems, according to SolmeteX.

Labor is required to change out 4 resin columns every 90 days and is observed to be less than 1 hour per quarter for a single EMS unit. Each Cartridge Replacement Kit costs approximately \$750, for a total of approximately \$3000/yr for a single EMS unit. For multiple units, costs associated with plumbing, electrical, maintenance, and labor are incurred.

Cost Comparison

This section is intended to provide details regarding cost comparisons that illustrate economic benefits of the SolmeteX EMS point of generation system compared to traditional systems, such as standard ion exchange systems in a similar application. However, in this case, the SolmeteX system is not comparable to traditional ion exchange systems because the EMS system performs a different function from the traditional systems.

The EMS system was designed for hospital clinical laboratory waste streams, and is comprised of multiple components in a single unit, whereas ion exchange systems are single component systems designed only to remove the target contaminant, in this case mercury. In addition to removing mercury, the EMS system includes unit processes that treat other waste stream contaminants, particularly organics. It also includes a pretreatment system which speciates the mercury for optimum binding to the resin, pre- and post-filtration, and pH control.

Although both systems remove mercury from wastewater, traditional ion exchange systems are typically designed to remove bulk contamination from a waste stream while the SolmeteX system functions most cost-effectively as a polishing step to reduce the levels of mercury in the wastewater to within acceptable discharge levels after the bulk contamination has been removed through ion exchange. Traditional ion exchange systems cannot reduce the mercury concentration to such low levels. Thus, the two systems perform different functions.

SolmeteX participated in a bench-scale feasibility study for the Technology Identification Subgroup of the Phase II Massachusetts Water Resources Authority/Medical Academic and Scientific Community Organization, Inc. (MWRA/MASCO) Mercury Work Group, End-of-Pipe Subcommittee. This study was focused on mercury removal from a hospital's clinical laboratory wastewater stream, and included bench-scale feasibility tests of six mercury removal technologies. The results of the study were compiled and reported in the *MWRA/MASCO Mercury Work Group Phase II End-Of-Pipe Subcommittee Technology Identification Subgroup Report*, dated December 1997. The report also contains preliminary economic information, but it is important to note that the bench-scale feasibility testing project could only produce rough full-scale cost estimates. Copies of the report can be obtained by calling the MWRA at (617)242-6000 ext. 4900 and asking for the Technical Services Department. For more information, please contact:

Massachusetts Water Resources Authority
Charlestown Navy Yard
100 First Avenue
Boston, MA 02129
www.mwra.state.ma.us

Medical Academic and Scientific Community
Organization, Inc.
375 Longwood Avenue
Boston, MA 02215
www.masco.org



Regulatory/Safety Requirements

This section provides information regarding applicable regulations and regulatory agencies related to the implementation of the SolmeteX technology system as identified by the vendor in the experience to date with the technology.

Applicable Regulations

Applicable Massachusetts regulations/regulatory authorities which apply to the SolmeteX technologies include the Massachusetts Clean Waters Act, Code of Massachusetts Regulations (CMR), Massachusetts Department of Environmental Protection (DEP), and the MWRA requirements. Note: The information presented in this section was adapted from the STEP Technology Assessment, dated March 7, 1997.

Massachusetts Clean Waters Act - Under the Massachusetts Clean Waters Act, DEP's Industrial Wastewater (IW) program regulates systems which treat industrial or hazardous wastewater generated on site and resulting in discharges of effluent.

Current regulations require plan review of the treatment systems and permits for discharges. Significant changes in a wastewater treatment system require evaluation by regional permitting staff. Replacing one type of ion exchange technology with another, or the use of Metall:X™ in place of another precipitating chemical would not be likely to trigger a full review.

MWRA- The MWRA administers the state's sewer discharge regulations within its service area, and does not require plan approvals for industrial treatment systems. Permits are required as presented in the following section.

The MWRA regulates mercury discharge through a permitting process for industrial facilities located within its service area:

- ▶ 360 CMR 10.024(1)(a) states that any discharge of mercury is prohibited. The MWRA developed an enforcement limit for its mercury prohibition at 1.0 ug/L based upon a recognition that the method detection limit of EPA Method 245.1 for mercury in wastewater samples was typically 0.2 ug/L. Thus, a wastewater sample measuring greater than 1.0 ug/L (which is five times the typical method detection limit) would assuredly contain the prohibited mercury.
- ▶ 257 CMR 2.00 requires that operators of wastewater treatment facilities be certified, to ensure that they have appropriate experience and training and the systems are properly maintained and operated.

Operator certification regulations may apply to the SolmeteX system. In order for SolmeteX to determine the level of operator likely to be required to operate its end-of-pipe systems, a determination of their grades based on a "pumping and instrumentation" description of the Metall:X™ and Keyle:X™ technologies must be made for each facility which purchases a unit.

Currently, shipment off-site appears to be the most likely option for the sludge resulting from the Metall:X™ process and the spent resin cartridges resulting from the Keyle:X™ process.



- ▶ 310 CMR 30.00 requires facilities which generate hazardous waste or concentrate industrial wastes to a level at which they become hazardous wastes, or those which concentrate already-hazardous wastes, to register as generators of hazardous waste. Waste is classified as hazardous based either on the source of the material or on its physical characteristics, e.g. corrosivity, ignitability, toxicity.
- Requirements for disposal of hazardous waste include testing and characterization of the waste, use of a manifest by a licensed transporter, and disposal in a hazardous waste landfill.

Please contact the MWRA directly for further information regarding the MWRA regulations.

Permit Requirements

The hospital where the SolmeteX system was implemented is subject to the MWRA industrial sewer use discharge permit requirements set forth in 369 CMR 10. Please note that these permit requirements apply to the facility in which the technology is implemented, and not necessarily to the technology itself. These regulations apply to hospitals within the MWRA system, and therefore would apply to the hospital at which the EMS point of generation system was implemented.

The MWRA regulations specify wastewater pollutant limitations in the following sections:

360 CMR 10.021	General Prohibitions
360 CMR 10.023	Specific Prohibitions
360 CMR 10.024	Specific Discharge Limits/Local Limits

A separate section of MWRA regulation states the permit requirements for photo processing and printing operations. Compliance with 360 CMR 10.061 would be necessary for application of this technology at photo processing and printing facilities, but not for the histology laboratory application.

However, no additional permits were required for implementation of the SolmeteX technology at the Boston hospital.

Regulatory Interaction

As no additional permits were obtained for this application, waiting times required for permits and formal approvals required from regulators required for the implementation of the SolmeteX technology are not applicable.

Health/Safety Issues

The following presents health and safety issues identified by SolmeteX.

Standard requirements applicable to treatment systems to which the SolmeteX system must subscribe including the following:



- ▶ adherence to fire protection, plumbing, and wiring codes, which may include permitting and explosion-proof electronics;
- ▶ OSHA hazardous waste safety, handling, and disposal training for operators, as applicable for purchase, transportation, storage, and handling of the pretreatment chemicals;
- ▶ periodic system monitoring and inspection to ensure that the system operations are normal and that the level in the oxidant/disinfectant tank is adequate.

Additional safety considerations include:

- The SolmeteX point of generation systems are designed to be connected directly to the analyzer and operate in a "hands off" mode. Operator interaction occurs during column change-out and replenishing of pretreatment chemicals, therefore operator training is required to ensure proper and safe handling, storage, transportation, and disposal of pretreatment chemicals.
- ▶ The columns are self-sealing, therefore there are no continuous exposure hazards. The spent columns do need to be manually disconnected and replaced, therefore safe work practices should be exercised and appropriate personal protective equipment (PPE) should be worn during column change-out to minimize exposure risks.
- ▶ The SolmeteX technology is self-contained. There have been no reported incidences of leaks or spills in the system.
- ▶ Material Safety Data Sheets (MSDS) are available for the resins.
- ▶ The system cannot operate if the resin has reached capacity. The system is equipped with audio and visual alarms which are triggered approximately 10 days before the system has reached its specified design capacity, which is approximately 10 days before actual breakthrough. The alarms are continuously activated until the cartridges are changed.
- ▶ The system is equipped with system alarms. In addition, the system pumps are equipped with alarms to sound in the event of pump failure.
- ▶ Safe work practices should be exercised and appropriate PPE should be worn while handling the pretreatment chemicals. MSDS for all pretreatment chemicals should be maintained on-site and workers should be familiar with the information contained in the MSDS.
- ▶ The system is in compliance with applicable OSHA and health and safety regulations.



Lessons Learned/Implementation Issues

This section presents the lessons learned regarding the SolmeteX applications discussed herein.

- The design of the Keyle:X™ material allows for increased binding capacity and reaction kinetics, as well as increased physical and chemical stability of the inert support structure, compared to existing traditional technologies.
- The SolmeteX systems are designed to operate as point of generation systems, which would minimize the amount of wastewater that requires treatment.
- The SolmeteX system could be integrated with existing treatment systems.
- ▶ A potential application for the SolmeteX systems is as zero-discharge systems, in which there is no discharge to surface waters, groundwater or sewers, and process chemistries are either recycled to the process or shipped off as hazardous waste. The use of zero discharge technology is sometimes limited by a costly permitting requirement that requires facilities which treat hazardous waste or wastewater be licensed.

Benefits Derived From Application

The following presents benefits of the SolmeteX system to the user as demonstrated at the applications discussed herein in contrast to typical ion exchange or chemical precipitation technologies.

SOLMETEX SYSTEM BENEFITS

- | | |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ul style="list-style-type: none"> ▶ Uses less resin. Volume of Metall:X™ required is approximately 20-25% less than conventional precipitation technologies. ▶ Increased selectivity and higher capacity for target metals ▶ Smaller capital investment and low per gallon operating cost ▶ Removes and concentrates mercury onto a solid medium for potential recovery ▶ Bound Metall:X™ resin/metal complex passes TCLP testing (non-hazardous waste). Spent Keyle:X™ resin is a non-hazardous waste | <ul style="list-style-type: none"> ▶ Point of generation systems offer source reduction ▶ Meets low regulatory discharge levels ▶ Operates effectively at high flow rates ▶ Reduces interference from other waste stream ions ▶ Integrates with existing treatment systems ▶ After the metal recovery process (thermal reclamation at off-site facility), the Keyle:X™ resin is reduced to approximately 10% of its initial volume |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|



Limitations In Application

- Pretreatment of the wastewater before introduction into the SolmeteX resin columns is always necessary due to the presence of organic complexes and particulate/colloidal bound forms of mercury. Pretreatment is included as part of the standard SolmeteX process.
- Well-distributed flow through the vessel containing the resin is important to ensure that the resin is most efficiently utilized. This is accomplished through the use of manifolds and flow distributors at the bottom of the vessel.
- ▶ The Keyle:X™ resin is not regenerable. The mercury is retorted by incineration, as caustic solution does not release mercury in the ion exchange regeneration process.

